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Changes in Physiological and Physico-Chemical Characteristics of Banana Fruits at Various Storage Temperatures

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Temperature and storage period play an important role in ripening process of banana. To get banana with good quality and longer shelf life, it is imperative to determine storage characteristics at different temperatures. The banana cultivars *viz.* Williams, Zeling and Grand Nain were packed in polyethylene bags and then stored at room temperature (32±2ºC), cold storage (20±2ºC) and deep freezer (4±2ºC). Changes in physiological, physico-chemical and physical (sensory) parameters were recorded at 3 days intervals till rejectable condition of fruit. There was increase in physical loss in weight and pulp peel ratio with increase in storage period. Increase in TSS, acidity and moisture was also noticed as storage period increased. Sugar of banana fruit increased as ripening advanced. The quality of banana was found safe for 32 days at 20ºC storage, 21 days at 32ºC and 5 days at 4ºC.

Key words: Banana, Physico-chemical characteristics, Storage characteristics, Shelf life, Storage temperature.

Banana is one of the commercially important fruits with a highly organized international trade. It provides more balanced diet that many fruits. Shelf life of fully matured banana under tropical conditions is limited to a short period. During peak season when larger volumes of fruits are available, the producers face lower returns due to its perishable nature. Therefore, a need to increase shelf life of banana is well recognized. Its shelf life has to be extended by keeping the fruits at appropriate temperature, because temperature plays an important role in ripening process. The fruits are normally dispatched to the market immediately after harvesting and these attain ripening on many parts of India. As a result, burn injury occurs on fruits. In the present investigation, the shelf life of banana fruits was monitored by taking observations at regular interval at 3 different temperatures.

Materials and Methods

Mature fruits of the banana cultivars *viz*. Williams, Zeling and Grand Nain were packed in polyethylene bags with ventilation and stored at three temperatures *viz.* 32±2, 20±2 and 4±2ºC. Changes in physico-chemical parameters were recorded at 3 days intervals till the fruits attained to rejectable stage. The physiological properties observed include physiological loss in weight (PLW) and pulp/peel ratio. For determining PLW, each sample was weighed individually at regular interval and cumulative losses in weights were calculated. Similarly, pulp and peel were separated, weighed individually and expressed as pulp/peel ratio. For chemical analysis, pulp of each sample was ground and then known amount of samples were weighed for determining the following physico-chemical parameters.

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Total soluble solids (TSS) and moisture content

The TSS of each sample was recorded by using Erma Hand Refractometer and expressed in ºBrix. The Moisture meter (Mettler LJ16) was used to determine moisture content by drying samples of 5 g of banana pulp.

Titratable acidity

The acidity of banana pulp was analysed by titrating it with the standard N/10 NaOH solution using phenolphthalein as an indicator (Ranganna, 1986). Pulp of each sample (5 g) was taken in a conical flask and then 100 ml distilled water was added in it and mixed well. Then 2-3 drops of phenolphthalein indicator was added and titration was done with N/10 NaOH solution. Burette reading was taken on appearance of faint pink colour in the colourless solution. Titrable acidity of banana pulp was calculated by using the following formula.

$$\%\ \text{Tirable acidity} = \frac{6.4 \times \text{Burette Reading} \times \text{Normality of NaOH}}{\text{Weight of sample}}$$

Sugar content

The sugar content of banana was determined by Lane and Eyon's method as suggested by Ranganna (1986). Fehling's solution A was prepared by dissolving 69.28 g of copper sulphate ($CuSO_4.5H_2O$) in water diluted to 1000 ml. Fehling's solution B was prepared by dissolving 346 g of

Rochelle salt (potassium sodium tartate, KNa $C_4H_4O_6.H_2O$) and 100 g NaOH in water, diluted to 1000 ml.

Total sugar

Each sample (5 g of pulp) was taken in 100 ml conical flask and 5 ml HCl was added to it and mixed well. After 24 h stand, content was filtered through cotton. Solution of 40% NaOH (5-10 ml) and 2 drops of phenolphthalein were added to the filtrate. Using distilled water, volume was made up to 100 ml. 2 ml Fehling's solution (2 ml=1 ml of A + 1 ml of B) was taken in another conical flask and boiled. Then titration was done with fitrate solution taken in burette using methylene blue as indicator. Burette reading was taken when colour changed from faint pink to brick red (Ranganna, 1986). Total sugar was calculated using the following formula.

$$\text{Per cent sugar} = \frac{\text{Fehling factor x volume of filtrate x 100}}{\text{5 x Burette Reading x weight of sample x 1000}}$$

where, Fehling factor = 53.75

Reducing sugar

Each sample (5 g of pulp) was taken in 100 ml conical flask and 50 ml distilled water was added in it and mixed well. After half hour stand, content was filtered through cotton. Using distilled water, 100 ml volume was made up to Fehling's solution (2 ml = 1 ml of A + 1 ml of B) was taken in another conical flask and boiled. Then titration was done with filtrate solution taken in burette using methylene blue as indicator. Burette reading was taken when colour changed from faint pink to brick red. Reducing sugar was calculated by using same equation as was done for total sugar.

Results and Discussion

Physico-chemical composition

The physico-chemical composition of three banana varieties at time of harvest is given in Table 1. The physiological loss in weight and pulp / peel ratio have also been estimated and the results presented.

Physiological loss in weight

Fom Table 2, it is clear that physiological loss in weight of banana fruits increased with the increase in storage duration in all varieties at various temperatures. This may due to transpiration and respiration losses. The relationship between PLW and storage days was found to be linear upon regression analysis for all samples. The high value of coefficient of correlation (0.83 to 0.99) indicated that storage days is the most important and responsible factor for PLW of banana.

Table 1. Physico-chemical composition of banana

Name of the varieties	pH	TSS(^{o}Brix)	Acidity(%)	Moisture(%)	Total sugar(%)	Reducing sugar (%)	Non-reducing sugar (%)
Williams	5.11	3.2	0.0070	70.76	0.138	0.113	0.025
Zang	5.12	3.5	0.0074	70.04	0.141	0.115	0.026
Grand Nain	5.10	3.6	0.0070	70.14	0.142	0.116	0.026

Pulp/peel ratio

The relationships between pulp/peel ratio and storage day is given in Table 3. The pulp/peel ratio of banana fruits increased with the increase in storage period in all varieties at all temperatures. This may due to osmotic transfer of moisture from peel to pulp. At 20^{o}C storage, there was uniform rise in pulp/peel ratio with the increase in storage days as compared to storage at 32^{o}C. This may be due to proper progress in ripening at 20^{o}C. During storage at 4^{o}C, the lower rise in pulp/peel ratio was possibly due to occurrence of chilling injury. Chlorophyll is present; in the peel and when banana is stored at lower temperature, the inorganic components of chlorophyll i.e. Copper and Nickel oxidize and their bonds are loosened. The Chlorophyll decomposes and becomes blackish. Similar observations were reported by Desai and Deshpande (1975). The relationship between pulp/peel ratio and storage days was found to be linear upon regression analysis for all samples. The high value of coefficient of correlation (0.89 to 0.99) indicated that there is relationship between pulp/peel ratio and storage days.

Table 2. Relationship between PLW and storage days at various temperatures

Storage temperature, ^{o}C	Varieties	Equation	Coefficient of correlation
32	Williams	Y=4.47+0.27 X	0.83
	Zeling	Y=2.81+0.40 X	0.95
	Grand Nain	Y=3.94+0.39 X	0.92
20	Williams	Y=2.69+0.26 X	0.95
	Zeling	Y=4.36+0.28 X	0.90
	Grand Nain	Y=3.50+0.31 X	0.94
4	Williams	Y=-2.13+0.63 X	0.96
	Zeling	Y=1.24+0.55 X	0.96
	Grand Nain	Y=0.90+0.51X	0.99

(Note: X indicates storage periods and Y indicates PLW)

Table 3. Relationship between pulp/peel ratio and storage days at various temperatures

Storage temperature, ^{o}C	Varieties	Equation	Coefficient of correlation
32	Williams	Y= 1.39 + 0.031 X	0.92
	Zeling	Y= 1.70 + 0.042 X	0.86
	Grand Nain	Y= 1.44 + 0.035 X	0.89
20	Williams	Y= 1.38 + 0.02 X	0.99
	Zeling	Y= 1.48 + 0.02 X	0.98
	Grand Nain	Y= 1.38 + 0.02 X	0.97
4	Williams	Y= 1.02 + 0.03 X	0.99
	Zeling	Y= 1.34 + 0.02 X	0.98
	Grand Nain	Y= 1.33 + 0.02 X	0.98

(Note: X indicates storage periods and Y indicates PLW)

Table 4. Relation between TSS and storage days at various temperatures

Storage temperature, °C	Varieties	Equation	Coefficient of correlation
32	Williams	Y=1.05+0.63X	0.94
	Zeling	Y=1.61+0.72X	0.97
	Grand Nain	Y=1.23+0.77X	0.97
20	Williams	Y=0.33+0.46X	0.90
	Zeling	Y=0.70+0.58X	0.89
	Grand Nain	Y=0.24+0.52X	0.89
4	Williams	Y=3.87+0.041X	0.56
	Zeling	Y=3.60+0.025X	0.42
	Grand Nain	Y=3.69+0.013X	0.53

(Note: X indicates storage periods and Y indicates PLW)

Physico-chemical characteristics

Total soluble solids (TSS)

The relationships between TSS and storage days (Table 4) was found to be linear upon regression analysis for sample kept at 20°C and 4°C. The high value of coefficient of correlation (0.89 to 0.99) for storge of banana at 32 and 20°C indicated that there exists a high degree of relationship between variables of TSS and storage days. For 4°C, value of coefficient of correlation R^2 (0.42 to 0.53) indicated that there exists moderate degree of relationship between TSS and storage days. In general, the TSS of banana fruits increased with the increase in storage duration in all varieties. However, there was difference in behaviour of fruits when stored at various temperatures. For 32°C storage, the increase in TSS was negligible up to 9 days but then it acquired appreciable increase while at 20°C storage, the increase of TSS was insignificant upto 24 days and then it suddenly shooted up. This may be due to conversion of complex polymer into simple substances. In contrast to above, at 4°C, the value of TSS decreased after 21 days of storage possibly because of decomposition of carbohydrates into CO_2 and H_2O. These observations are in agreement with the finding of Madamba *et al*. (1977).

Table 5. Relationship between titrable acidity and storage days at various temperatures

Storage temperature, °C	Varieties	Equation	Coefficient of correlation
32	Williams	Y=0.0013+0.018X	0.97
	Zeling	Y=0.0009+0.017X	0.97
	Grand Nain	Y=0.0023+0.015X	0.95
20	Williams	Y=0.0069+0.0012X	0.99
	Zeling	Y=0.0050+0.0012X	0.99
	Grand Nain	Y=0.0069+0.0011X	0.99
4	Williams	Y=0.0072+0.0016X	0.99
	Zeling	Y=0.0061+0.0016X	0.98
	Grand Nain	Y=0.0057+0.0017X	0.98

(Note: X indicates storage periods and Y indicates PLW)

Titrable acidity

For all the varieties, titrable acidity tended to increase with the advancement in the duration of storage period at all temperatures which is indicated by regression equation shown in in Table 5. This may be due to decomposition of starch. Banana stored at 4°C showed lower percentage of acidity as compared to fruits stored at 32 and 20°C because at 4°C, chilling injury occurred in the fruits and they failed to ripen. These results are in agreement with the findings of Aziz *et al.* (1976) and Wahab and Nawwar (1977). The relationship between titrable acidity and storage days (Table 5) was found to be linear upon regression analysis for all samples. The high value of coefficient of correlation (0.95 to 0.99) indicated that there exists a high degree of relationship between titrable acidity and storage days.

Table 6. Relationship between Moisture percentage and storage days at various temperatures

Storage temperature, °C	Varieties	Equation	Coefficient of correlation
32	Williams	Y=5.11+0.008X	0.99
	Zeling	Y=5.13+0.009X	0.90
	Grand Nain	Y=5.12+0.010X	0.89
20	Williams	Y=5.11+0.007X	0.97
	Zeling	Y=5.11+0.008X	0.97
	Grand Nain	Y=5.12+0.006X	0.99
4	Williams	Y=5.13+0.008X	0.97
	Zeling	Y=5.14+0.007X	0.97
	Grand Nain	Y=5.10+0.007X	0.95

(Note: X indicates storage periods and Y indicates PLW)

Moisture content

Of the various factors which affect the quality of banana, moisture content is the most important. In the present study, moisture of banana increased with increase in storage duration in all varieties. This may be due to movement of water from peel to pulp. Higher temperature (32°C) might have caused almost total transfer of moisture thereby it become pulpy with high moisture deterioration in its quality. At 4°C, due to occurrence of chilling injury, the fruits became black and watery resulting in an increase in moisture percentage during storage. Similar results were reported by Awan and Ndubizn (1978). The relationship between moisture and storage days (Table 6) was found to be linear upon regression

Table 7. Relationship between total sugar percentage and storage days at various temperatures

Storage temperature, °C	Varieties	Equation	Coefficient of correlation
32	Williams	Y=0.33+0.020X	0.63
	Zeling	Y=0.32+0.030X	0.62
	Grand Nain	Y=0.28+0.035X	0.60
20	Williams	Y=1.72+0.21X	0.87
	Zeling	Y=2.50+0.31X	0.80
	Grand Nain	Y=2.10+0.26X	0.82
4	Williams	Y=0.19+0.0071X	0.80
	Zeling	Y=0.20+0.0078X	0.81
	Grand Nain	Y=0.20+0.0078X	0.80

(Note: X indicates storage periods and Y indicates PLW) analysis for all samples. The high value of coefficient of correlation (0.89 to 0.99) indicated that there exists a high degree of relationship between moisture and storage days.

Total sugar

Table 7 showed the positive relationships between total sugar percentage and storage days for all varieties of banana at 32 and 20°C. However, for 4°C the variety William has shown positive relationship while Zeling and Grand Nain had showed negative relationship. The relationships between total sugar and storage days were found to be linear upon regression analysis for samples kept at 32 and 20°C. The high value of coefficient of correlation (0.60 to 0.87) indicated that there exist moderately high degrees of relationship between total sugar percentage and storage days. For 4°C, value of coefficient of correlation (0.80 to 0.81) indicated that there exist particularly high degrees of relationship between total sugar and storage days.

The increase in total sugar may be due to conversion of starch into sugar. At 4°C storage temperature, there may be breakdown of sugar into alcohol due to fermentation. These results are in agreement with the finding of Aziz *et al.* (1976) and Carvalho *et al.* (1990). The maximum amount of sugar was found in samples of all varieties during storage at 20°C. Therefore, 20°C is a most suitable temperature for storage of banana as compared to 32 and 4°C. Hence, 20°C storage temperature can be strongly recommended for storage of all varieties of banana.

Table 8. Relationship between reducing sugar and storage days at various temperatures

Storage temperature, °C	Varieties	Equation	Coefficient of correlation
32	Williams	Y=0.33+0.013X	0.67
	Zeling	Y=0.32+0.017X	0.67
	Grand Nain	Y=0.32+0.017X	0.62
20	Williams	Y=0.63+0.09X	0.74
	Zeling	Y=1.15+0.14X	0.73
	Grand Nain	Y=0.99+0.12X	0.74
4	Williams	Y=0.16+0.0062X	0.62
	Zeling	Y=0.16+0.0063X	0.58
	Grand Nain	Y=0.16-0.0064X	0.77

(Note: X indicates storage periods and Y indicates PLW)

Reducing sugar

The relation between reducing sugar percentage and storage days (Table 8) was found to be linear upon regression analysis from sample kept at 32 and 20°C. The high value of coefficient of correlation (0.62 to 0.74) indicated that there exists a moderately higher degree of relationship between reducing sugar percentage and storage days. For 4°C, value of coefficient of correlation (0.58 to 0.77) indicated that there also exists a moderate degree of relationship between reducing sugar percentage and storage days.

There was increase in reducing sugar percentage as storage period increase in Williams, Zeling and Grand Nain varieties at 32, 20 and 4°C temperature. This may be due to hydrolysis of sucrose. Progress in ripening, reducing sugar percentage increased considerably. As chilling injury occurred in fruits, when stored at 4°C, they failed to ripen and there may be inhibition of starch to sugar conversion. These results are in agreement with the findings of Desai and Deshpande (1975).

Conclusion

Titrable acidity, TSS, moisture content, total sugar and reducing sugar content of banana samples increase during storage. Very low temperature (4°C) is not suitable for storage of banana because bananas are chilling sensitive. Deterioration of banana fruits occurred at high temperature (32°C) and therefore high temperature is also not suitable for storage of banana. Cold storage (20°C) was found to be most suitable temperature for storage of banana as compared to 32 and 4°C. Williams variety of banana had showed higher storage stability than Grand Nain and Zeling under varieties cold storage.

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